INTEGRATED PIPELINE PROJECT

Los Angeles NACE International
Valentine’s Day 2013 Meeting

Dr. Graham E.C. Bell, PE
Senior Vice President and
Principal Professional Associate
Business Class Director
Corrosion Control and Condition Assessment

Program Services Required Participation, Input and Consensus from Many Organizations

HDR|Schiff and HDR
- Jeff Giddings, PM
- Julie Bell
- Brien Clark
- Richard Pousard
- Leo Solis
- Tom Eynon
- Matt Thomas
- Jim Cathcart
- John Plattsmier
- Doug Biglen

Subconsultants and Other Program Resources
- Russell Corrosion Consultants
- V&A Engineering
- AECOM
- TRWD
- DDT’s
- UT-Arlington
- PUC Suppliers
- IFJ Suppliers
- Shrink Sleeve Suppliers
- Pipe Suppliers
I usually have a captive and attentive audience

The Integrated Pipe Line (IPL) Program is a joint Water Source Development for TRWD & DWU
TRWD & DWU Supply Systems

The Regional Partnership saves Money and Builds Community

Total Projected Capital Investment:

$2.3 Billion
<table>
<thead>
<tr>
<th>Segment</th>
<th>Diameter (inches)</th>
<th>TRWD Capacity (mgd)</th>
<th>DWU Capacity (mgd)</th>
<th>Length (mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/10/11</td>
<td>84</td>
<td>197</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>12/13/14</td>
<td>108</td>
<td>197</td>
<td>150</td>
<td>27</td>
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<tr>
<td>15</td>
<td>108</td>
<td>197</td>
<td>150</td>
<td>30</td>
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<tr>
<td>17/18</td>
<td>108/108</td>
<td>127</td>
<td>0</td>
<td>13</td>
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<tr>
<td>16</td>
<td>96</td>
<td>70</td>
<td>0</td>
<td>11</td>
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<tr>
<td>19</td>
<td>84</td>
<td>0 (ROW only)</td>
<td>150</td>
<td>42</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>--</strong></td>
<td><strong>--</strong></td>
<td><strong>--</strong></td>
<td><strong>148</strong></td>
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</table>
Two Candidate Pipe Materials with 4 Suppliers were Identified.

- Steel Pipe (AWWA C200) with Polyurethane Coating per AWWA C222 and Cement Mortar Lining per AWWA C205
- Prestressed Concrete Cylinder Pipe (AWWA C301/C304)
- American Spiral Weld
- Ameron/NOV
- Hanson
- Northwest Pipe

100 Year Design Life is the Stated Goal of the Program

Polyurethane as a coating and lining for steel pipe is a relatively new “Standard”

- AWWA C222
  - First Approved in 1999
  - Current Approved 2008
  - Based on Madison Chemical Product.
AWWA C222 is the Foundation of the Specification

The number and scale of major changes introduced into the most recent version of AWWA C222 indicates the standard is still in flux. Overall, the most recent standard sets the essential requirements for polyurethane materials including substrate surface preparation, coating application, testing, handling, and packaging. Table 2 summarizes the standard performance requirements for a laboratory-applied coating, as specified in AWWA C222.

The Objective is to Produce a Technical Specification to Achieve Project Goals

- Long Asset Life for the Owner
- Basis for Spec is AWWA C222
- Practical, Biddable and Constructible
- Technical understanding based on experience from other projects and research
- Fair and balanced approach to competition
Work for IPL and others identified porosity in AWWA C222 PU films

IPL Plant Results were similar to hand applied materials from previous study
Characteristics of PUC’s are related to Microstructure

- Polyurethane coatings are not truly hydrophobic
  - Allows for water absorption and vapor transmission
- Pores do effect water transmission
  - More connective pores - faster rate of water vapor transmission
  - Large pore volume - more water absorption
Minimum Thickness increased to 35 mils to Account for Reality Entrainment Observed in Plant Applied Materials

The Fundamental Premises of the IPL Spec are Based on Physics and Experience

- The primary purpose of a barrier coating is to separate the substrate from the corrosive environment
  - Low Moisture Permeation
  - Low Moisture Absorption
  - Adhesion to substrate
- Most coatings problems are applicator related
  - Surface Prep
  - Surface Prep
  - Mixing related issues
- **Coating protection during storage in the hot Texas sun...**
Polyurethane is a thermosetting polymer

- A thermosetting polymer is a prepolymer in a soft solid or viscous state that changes irreversibly into an infusible, insoluble polymer network by curing.
- Temperature and temperature cycling must consider glass transition temperature (Tg) for Polyurethane material.

Across the T_g, material is not physically stable and irreversible

[Diagram showing the chemical structure of Polyurethane and its modulus over normalised temperature (T/T_g).]
### Table: Glass Transition Temperature, Tg*

<table>
<thead>
<tr>
<th>Coating</th>
<th>Temperature, Tg*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating Q</td>
<td>66 C (151 F)</td>
</tr>
<tr>
<td>Coating R</td>
<td>56 C (133 F)</td>
</tr>
<tr>
<td>Coating S</td>
<td>50 C (122 F)</td>
</tr>
<tr>
<td>Coating T</td>
<td>54 C (130 F)</td>
</tr>
<tr>
<td>Coating U</td>
<td>55 C (131 F)</td>
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</table>

Pipeline construction practices may dictate long term exposure to elements

- Hot in Texas
- UV Intensity
- How Long Can Pipe Lay in Sun Before Damage is done?
- What can be done to protect and not break the bank?
Texas Baked Pipe was Available

How hot does it get???
Turns out, it gets pretty darn hot... 150 to 160 F

Mitigation Methods....
Quick Summary of the Findings and Fixes

- Temperatures are at and above the Tg for most candidate coatings
- Max Temperature depends on Pipe Color and Orientation to Sun
  - Dark Coatings Get Hotter than Light Coatings
  - 160 F max vs. 120 F Max
- Shielding with Tarp Reduces Temperatures
- 6 O’Clock Less than 2 or 10 O’clock


Thermal Sample #3
Does Getting Hot and UV Exposure Impact Coating???

- Surface effects dominate
  - Loss of Gloss
  - Unknown ablation of surface
- Tensile Pull Off (Adhesion) NOT a good indicator of Changes

<table>
<thead>
<tr>
<th>Unexposed</th>
<th>60 °C, 1 week</th>
<th>60 °C, 4 weeks</th>
<th>Accelerated Weathering, 1 week</th>
<th>Accelerated Weathering, 4 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>5130 psi (920 MPa)</td>
<td>4880 psi (210 MPa)</td>
<td>5230 psi (470 MPa)</td>
<td>4760 psi (450 MPa)</td>
<td>4940 psi (370 MPa)</td>
</tr>
</tbody>
</table>

ASCE Pipelines 2014, Stuart Croll et al., “Long Term Weathering Effects on Aromatic Polyurethane Coated Pipe”

How long is too long????
Detailed Analysis of FTIR, Optical Microscopy Supports 180 Day Exposure Limit

- State of the Art FTIR Allowed Profiling of Chemical Bond Changes
  - Loss of Cross Linking
- Surface Profile Imaging Allows Estimates of Surface Ablation
  - Damage was as much as 10 mils in 23 months

ASCE Pipelines 2015, Julie Bell et al., “TBD”

IPL PUC Specification Details were Developed and Consistent with Project Goals and Science

- Increases in Coating Thickness Increase Accounts for Application Methods and Surface Ablation
- Tensile Pull Off Strength is NOT an Indicator of Coating Effectiveness or Longevity
- Thermal Aging does Occur in Texas Sun
- Protection Required after 180 days
  - Light Surface Color
  - Tarps
  - Rotate the Pipe